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ORIGINAL RESEARCH

POSTERIOR SHOULDER TIGHTNESS AND SUBACROMIAL IMPINGEMENT CHARACTERISTICS IN BASEBALL PITCHERS: A BLINDED, MATCHED CONTROL STUDY

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ABSTRACT

Background: Baseball pitchers frequently develop varying levels of posterior shoulder tightness (PST) and often present with characteristics associated with subacromial impingement.

Purpose: To determine if a group of baseball pitchers with excessive PST (bilateral internal rotation ROM difference $>18^\circ$ and bilateral total arc of motion difference $>5^\circ$) have differences in subacromial joint space, forward scapular posture, or glenohumeral elevation range of motion (ROM) when compared to a control group.

Study Design: Descriptive, cross-sectional study.

Methods: Thirty-five asymptomatic professional baseball pitchers with excessive PST were matched with 35 pitchers with acceptable levels of PST. The investigators measured subacromial space using diagnostic ultrasound, glenohumeral elevation ROM using a digital goniometer, and scapular posture using a double square, and were blinded to the group of each participant. Separate t-tests were used to determine significant differences between groups ($p < 0.05$).

Results: The excessive PST group presented with significantly less subacromial space ($p = .0007$) and glenohumeral elevation ROM ($p = .03$) compared to the acceptable level PST group. The excessive PST group also had significantly more forward scapular posture than the control group ($p = .03$).

Conclusion: The baseball pitchers with excessive PST had less subacromial space and glenohumeral elevation ROM, as well as more forward scapular posture in their throwing arms compared to pitchers with acceptable levels of PST.

Level of Evidence: 3

Keywords: Baseball, glenohumeral, scapula, subacromial space

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INTRODUCTION

Because of the violent and repetitive nature of throwing a baseball, physical adaptations are common among pitchers. Numerous studies have demonstrated decreases in shoulder strength,[1,2] scapular kinematics,[3] hip range of motion (ROM) and strength,[4] as well as trunk ROM.[5] However, one of the most common and largest changes is the loss of glenohumeral internal rotation ROM in the throwing arm of pitchers compared to their non-throwing arm.[6,7] This loss is often the result of posterior shoulder tightness (PST).[6-8] Structures affected can include the posterior glenohumeral capsule,[8] as well as the posterior shoulder muscles,[7] such as the infraspinatus, teres minor, and posterior deltoid that are responsible for eccentrically controlling internal rotation and horizontal adduction during the follow through phase of the throwing motion.[9]

Although PST is a common characteristic among many baseball players, excessive losses in glenohumeral internal rotation can become pathologic. Pathologies such as internal impingement, SLAP lesions, UCL elbow sprains, and subacromial impingement syndrome have been associated with PST.[7,10-13] Subacromial impingement syndrome is the most commonly diagnosed shoulder pathology within the general population[14-16] and is also a frequent pathology seen in baseball pitchers.[17-20] This pathology contributes up to 67% of upper extremity injuries and 74 days on the disabled list experienced by major league baseball players annually.[21]

Along with symptoms of excessive PST, subacromial impingement patients also present with decreased subacromial joint space,[22] decreased glenohumeral elevation ROM,[23] and increased forward scapular posture, which can be the result of increased scapular protraction and anterior tilt.[24,25] Although the decreased glenohumeral elevation ROM may be an attempt to avoid soft tissue contact in patients with subacromial impingement[26] the decreased subacromial space and forward scapular posture may actually increase soft tissue contact.[27-30]

Excessive PST has been defined as a bilateral difference in glenohumeral internal rotation ROM of greater than 18° and a greater than 5° difference in the total arc of motion.[31] Despite the recognized PST in baseball pitchers and its relationship with subacromial impingement syndrome, it is not clear whether pitchers with excessive PST have an increased risk of characteristics associated with subacromial impingement syndrome. Being able to identify these potentially pathologic characteristics could provide clinicians an advantage for addressing such deficiencies and positively affecting movement strategies prior to injury. The purpose of this study was to determine if a group of baseball pitchers with excessive PST have differences in subacromial joint space, forward scapular posture, or glenohumeral elevation range of motion (ROM) when compared to a control group. The investigators hypothesized that asymptomatic pitchers with excessive PST would have less subacromial joint space, glenohumeral elevation ROM, and more forward scapular posture than pitchers without PST.

METHODS

All participants provided informed consent as mandated by the university's institutional review board prior to testing. The Institutional Review Board at Illinois State University approved the study and the rights of all participants were protected.

Seventy professional baseball pitchers volunteered to participate in this study. Thirty-five pitchers identified with excessive PST (31 right-handed, 4 left-handed) were matched to 35 control pitchers (20 right-handed, 15 left-handed) based on age, height, and mass (Table 1). These participants were chosen based on a sample of convenience. All participants were asymptomatic at the time of testing. Exclusion criteria consisted of any recent upper extremity injury (injury within past year) or any history of upper extremity surgery. An upper extremity injury was defined as any injury that caused the individual to miss any amount of time from practice or competition.

All testing was conducted in the athletic training room of the spring training facility of a professional baseball organization. No testing was conducted following any conditioning workout or throwing session. The same two investigators conducted all measurements for elevation ROM, subacromial joint space, and forward scapular posture, while separate investigators measured internal and external

Table 1. *Descriptive Participant Demographics (n = 70, all subjects were male).*

Group	Age (yrs)	Height (cm)	Mass (kg)
Excessive PST (n=35)	21.8±2.6	188.4±5.6	91.9±10.3
Control (n=35)	22.5±2.6	187.7±5.6	93.3±9.6

PST = posterior shoulder tightness.

ROM. Therefore, the investigators measuring the dependent variables (e.g. subacromial joint space, forward scapular posture, glenohumeral elevation ROM) were blinded to the group assignment of each participant.

Passive glenohumeral internal rotation, external rotation, and elevation ROM were measured using a Pro 3600 Digital Inclinometer (SPI-Tronic, Garden Grove, CA). All ROM measurements were conducted with the participant supine on a standard treatment table. For rotational motion the test shoulder was placed in 90° of abduction and neutral rotation. One investigator then stabilized the scapula by providing a posterior force to the anterior acromion while passively moving each participant's arm into either internal or external rotation until the first point of resistance. In this position a second examiner aligned the inclinometer with the forearm for measurement. The total arc of motion was calculated as the sum of maximum internal and external rotation. Elevation motion was measured with participants in the same position. One investigator applied a posterior force to the lateral border of the scapula and moved the shoulder until the first point of resistance in elevation. In this position the second investigator then aligned the inclinometer with the humeral shaft to determine the angle between the humerus and the horizontal plane. A priori intra-tester reliability was examined, and strong reliability was demonstrated for the investigators conducting these measurements (internal rotation ICC = 0.98, SEM = 2°, external rotation ICC = 0.95, SEM = 3°, and elevation ICC = .92, SEM = 3°).

Subacromial joint space was measured using the Terason t3000 M-series ultrasound system (Teratech, Burlington, MA). For this measurement each participate stood in a relaxed position with their shoulder in approximately 0° of abduction. The ultrasound head was placed over the lateral aspect of the acromion, as determined by palpation, and in line with scapular plane. From this single, static image the shortest distance between the inferior acromion and the humeral head was then measured using the ultrasound software caliper function. A priori intra-test reliability testing showed strong reliability (ICC = 0.83, SEM = 0.84mm) for the investigators conducting this measurement.

Forward scapular posture was measured using the double square method.[32] For this measurement each participant stood in a relaxed position with their back against a wall. An investigator then used the double square to measure the distance between the wall and the most anterior aspect of the acromion. The bilateral difference between forward scapular posture measurements was used to determine the amount of forward scapular posture for the throwing arm. The intra-tester reliability of this measurement had strong reliability (ICC = 0.84, SEM = 4.6mm).

The means and standard deviations for all dependent variables were calculated and separate paired *t* tests were run to determine significant differences between groups (IBM SPSS Statistics 22; IBM Corporation, Armonk, NY). Findings were considered significant at an alpha level of $p < 0.05$. Cohen's d effect sizes were determined to provide an indication of the clinical meaningfulness for between group differences. Effect size was calculated as excessive PST group mean – control group mean / control group standard deviation. Effect sizes were interpreted as small = 0.20, medium = 0.50, and large = 0.80.[33]

RESULTS

The descriptive glenohumeral ROM characteristics for each group can be viewed in Table 2. There were no between group differences for age, height, or mass ($p > 0.30$). The excessive PST group presented with significantly less subacromial space ($p = .0007$; effect

Table 2. *Descriptive Glenohumeral Range of Motion Characteristics by Group.*

Measurement	Excessive PST Group (n=35)	Control Group (n=35)
Internal Rotation ROM		
Throwing arm (°)	39±9	50±9
Non-throwing arm (°)	65±9	55±10
Bilateral difference (°)	-26±5	-5±9
External Rotation ROM		
Throwing arm (°)	114±10	108±12
Non-throwing arm (°)	101±11	103±12
Total Arc of Motion ROM		
Throwing arm (°)	153±10	157±15
Non-throwing arm (°)	166±12	157±12
Bilateral difference (°)	-13±9	0±9

PST=posterior shoulder tightness. ROM=range of motion (passive).
Negative values indicate less ROM in the throwing arm compared to the non-throwing arm.

Table 3. *Between Group Descriptive Statistics (mean ± standard deviation).*

Measurement	Excessive PST Group (n=35)	Control Group (n=35)	Difference	*p*-value	Effect Size
GH Elevation ROM	145±12	152±13	-5±18	0.03*	0.52
Subacromial Joint Space (mm)	10±2	12±2	-2±3	0.0007*	0.74
Forward Scapular Posture (mm)	9±10	3±11	5±15	0.03*	0.51

*Indicates statistically significant difference between groups ($p < 0.05$).
PST=posterior shoulder tightness; GH=glenohumeral; ROM=range of motion (passive).
Negative values indicate less ROM/space in the excessive PST group than the control group.

size = 0.74) and glenohumeral elevation ROM ($p = .03$; effect size = 0.52) than the control group (Table 3). The excessive PST group also had significantly more forward scapular posture of their throwing arm than the control group ($p = .03$; effect size = 0.51) (Table 3). All of the identified differences had moderate effects sizes. Furthermore, the between group differences were larger than their respective standard error of measurement suggesting clinical significance, as well as statistical significance.

DISCUSSION

Due to the recognized relationship between excessive PST and various shoulder disorders it is critical that clinicians understand how PST may contribute to the development of such pathologies. The results of this study are the first to show that baseball pitchers identified with excessive PST have decreased subacromial joint space, humeral elevation ROM, and increased forward scapular posture, which have all been linked to subacromial impingement syndrome.[34]

For the purpose of this study the investigators chose not to use the term glenohumeral internal rotation deficit or GIRD because they believe it can be misinterpreted. In the investigators' clinical experience most baseball players, especially pitchers, have a loss of glenohumeral internal rotation ROM in their dominant shoulder compared to their non-dominant. However, this loss can be attributed to bony and/or soft tissue adaptations. The bony adaptations come from an increase in humeral retroversion, which is often the result of increased rotational forces during the throwing motion while the athlete is still skeletally immature.[35] This increase in retroversion has actually been reported to reduce the risk of shoulder injury and causes an increase in GH external rotation ROM with a concomitant amount of loss in internal rotation resulting in no bilateral difference in the total arc of motion.[35] However, posterior soft tissue tightness would alter the total arc of motion because of lost internal rotation without the subsequent gain in external rotation.[36] The investigators of this study attempted to assess the loss of internal rotation caused by soft tissue contributions, which is why the bilateral difference in total arc of motion was used within the definition of excessive PST. Decreased total arc of motion may also be more problematic in regards to pathology than losses in GH internal rotation.[37]

The precise tissue(s) causing PST remains a topic of debate. Takenaga et al.,[8] reported that the posterior capsule in the throwing shoulder of baseball players is thicker and stiffer when compared to their non-throwing shoulder. Conversely, posterior rotator cuff stiffness has been suggested to limit internal rotation ROM.[7] Regardless of the specific structures involved, PST remains a common problem among pitchers and can result in various shoulder adaptations.[11,12,38] PST can cause a posterior-medial shift in the position of the humeral head on the glenoid resulting in decreased subacromial joint space,[11] which may partially explain the decreased subacromial space among the participants with excessive PST in the current study.

The pitchers in the excessive PST group also presented with less glenohumeral elevation ROM. Because the humeral head translates superiorly during humeral elevation,[39] Steenbrink et al.,[26] speculated that with a decreased subacromial joint space at rest there is less room for the humeral head to translate superiorly during humeral elevation prior to contact between the humeral head and subacromial arch. Externally rotating the humerus allows the greater tuberosity to clear the acromion;[40] however, the participants in the current study were in neutral rotation during the elevation ROM measurement. Therefore, the loss of glenohumeral elevation, in the participants with excessive PST, may be a preventative technique to avoid increased contact of the soft tissue structures and subsequent pain within a smaller subacromial joint space. However, further research is necessary to confirm this.

Laudner et al.,[41] identified an association between PST and increased forward scapular posture and hypothesized that PST causes the humeral head to pull the scapula forward during the follow through phase of the throwing motion, resulting in a more forward scapular position. The results of the current study, which found increased forward scapular posture among the excessive PST group, supports these previous findings. Furthermore, Solem-Bertoft et al.,[42] showed that as the scapula moves into a more forward position, such as with increased scapular protraction, the subacromial joint space decreases. This decreased space may then lead to increased contact pressure of the soft tissue structures[29] and ultimately to impingement.[22,27,28,30,43,44]

The subacromial joint space in asymptomatic shoulders has been reported to range from 8.7 – 11.1mm with the shoulder in a resting position.[22,45] Because this small space also houses several soft tissue structures, any reductions in this area, even minor changes, whether it be from humeral head superior migration or from scapular malposition, can result in significant increases in the contact pressure of the soft tissues structures.[24,27,43,44] Based on the results of the current study, the investigators suggest that excessive PST should be considered in the prevention, diagnosis, and rehabilitation of pathologies associated with decreased subacromial joint space, decreased glenohumeral elevation ROM, and increased forward scapular posture.

The investigators of this study would again like to emphasize that all participants were asymptomatic at the time of testing. Even the excessive PST group did not have pain despite having characteristics similar to those of subacromial impingement patients, such as limited subacromial joint space, decreased glenohumeral elevation, and increased forward scapular posture. There are various potential reasons why these individuals did not present with pain. Most notably, subacromial impingement can be caused by or the result of numerous physical abnormalities. Presenting with one or multiple of these aberrant characteristics does not necessarily result in pain.[34] For example, abnormal acromial shape, osteophyte formation, increased thoracic spine flexion, as well as weakness of the rotator cuff and periscapular muscles have all been associated with impingement.[34] Therefore, it is not surprising that the participants of the current study that had excessive PST in conjunction with deficient subacromial space, glenohumeral elevation, and scapular posture did not present with impingement pain. Furthermore, it is plausible that the detrimental characteristics present among these participants with excessive PST may have not be extensive enough to cause pain. As such, the investigators hypothesize that if the PST continues and the changes in subacromial space, glenohumeral elevation, and scapular posture worsen, the likelihood of pain could then increase in a concomitant fashion. However, future research is needed to prove this hypothesis.

There are limitations of this study. First, all participants were asymptomatic at the time of testing. Although, the excessive PST group presented with characteristics similar to those of patients diagnosed with subacromial impingement syndrome, such as decreased subacromial joint space, decreased glenohumeral elevation, and increased forward scapular posture, patients with shoulder disorders may present with different findings. Second, in a prior study examining thoracolumbar rotational ROM in pitchers, pitchers had greater active-assisted rotation to their non-dominant side compared to their dominant side.[5] It is possible that this postural adaptation could bias the ribs and thorax to be rotated to the non-dominant side in the resting position. Because the scapula sits on the posterior ribs, a rotated ribcage towards the non-dominant side would naturally cause the scapula to follow the ribs and present in a more protracted, anteriorly tipped, and internally rotated position. This in turn could create a less than optimal glenoid to humeral head alignment and give the perception of PST when assessing glenohumeral internal rotation ROM. Also, worth noting, the subacromial joint space was only measured in the resting position.

CONCLUSIONS

The results of this study demonstrate that baseball pitchers with excessive PST have less subacromial space, glenohumeral elevation ROM, and increased forward scapular posture in their throwing arms as compared to pitchers without excessive PST. Increased PST may be a precursor to pathologies associated with these shoulder characteristics, such as subacromial impingement syndrome.

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